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ESTABLISHING A HOUSING SEAL USING A FLEX SEAL ASSEMBLY

Field of the Invention

The claimed invention relates generally to the field of mechanical enclosures and more particularly, but not by way of limitation, to an apparatus and method for sealing a housing, such as a housing of a data storage device.

Background

Disc drives are digital data storage devices which store and retrieve large amounts of user data in a fast and efficient manner. The data are magnetically recorded on the surfaces of one or more data storage discs (media) affixed to a spindle motor for rotation at a constant high speed.

An array of vertically aligned data transducing heads are controllably positioned by an actuator to read data from and write data to tracks defined on the recording surfaces. An actuator motor rotates the actuator to move the heads across the disc surfaces. The heads are configured to be hydrodynamically supported adjacent the disc surfaces by fluidic pressures established by the high speed rotation of the discs.

It is generally desirable to control the interior fluidic environment within a data storage device housing. Seals are often employed to prevent the ingress of contaminants from the external environment. Moreover, some device designers have proposed hermetically sealed designs that utilize a lower density atmosphere, such as an inert gas (helium, etc.), to allow the device achieve higher levels of operational performance.

Disc drive designers are constrained by a number of factors, including continually reduced form factors and internal clearance issues, to provide effective internal fluidic control. With the continued demand for higher performance data storage devices, there remains a continual need for improved

housing configurations, and it is these and other improvements that the claimed invention is generally directed.

Summary of the Invention

As embodied herein and as claimed below, the present invention is generally directed to an apparatus and method for sealing a housing, such as a housing of a data storage device.

In one embodiment, the housing is formed of opposing, substantially planar first and second housing members and a peripherally extending flex seal assembly interposed between the housing members. The flex seal assembly comprises a flexible, thin-film heating member.

Dissipation of heat from current applied to the heating member causes one or more rings of sealing material to fuse to at least the first housing member. This results in the formation of a corresponding number of hardened seal joints at the seal assembly/housing interface. The sealing material preferably comprises solder or a low permeable, thermoset adhesive.

Preferably, the heating member comprises an elongated conductor, characterized as an electrically conductive trace, which is embedded within a flexible, thin-film dielectric ribbon. At least one fastener is preferably used to affix the first housing member to the second housing member and compress the flex seal assembly therebetween.

In some embodiments, the resulting seal joints are arranged into a plurality of nested, discrete rings each in a noncontacting relationship with the remaining rings. This facilitates the formation of an effective hermetic seal between the interior of the housing and the exterior environment.

In other embodiments, the resulting seal joints are arranged as a continuously extending spiral. When the opposing ends of the spiral are configured to be open to the interior of the housing and the exterior environment, respectively, an extremely long, elongated diffusion path can be created that extends along the gaps between adjacent joints, permitting pressure equalization and contaminant entrapment between the interior and exterior environments.

Preferably, a first set of the concentric rings of sealing material is placed on a first side of the heating member to fuse with the first housing member. A second

set of the concentric rings of sealing material is placed on an opposing, second side of the heating member to fuse with the second housing member.

In another embodiment, a flex seal assembly is provided as described above to establish a seal between opposing first and second housing members.

In another embodiment, a housing seal is formed by providing opposing, substantially planar first and second housing members, placing a flex seal assembly as described above between the first and second housing members, and applying current to the heating member to fuse the one or more rings of sealing material to at least the first housing member to form a corresponding number of hardened, concentric seal joints.

The method further preferably comprises a step of installing at least one fastener to affix the first housing member to the second housing member to compress the flex seal assembly therebetween prior to the applying current step.

The housing is subsequently unsealed by reapplying current to the heating member to loosen the sealing material, and removing the second housing member from the first housing member.

These and various other features and advantages which characterize the claimed invention will become apparent upon reading the following detailed description and upon reviewing the associated drawings.

Brief Description of the Drawings

FIG. 1 is a top plan representation of a data storage device having a housing which utilizes a flex seal assembly to establish a hermetic seal against an external environment, the flex seal assembly including a tab which supports a pair of electrically conductive pads to facilitate application of current to the assembly.

FIG. 2 provides a side elevational, cross-sectional representation of the device housing of FIG. 1.

FIG. 3 is a top plan representation of a heating member of the flex seal assembly comprising a circumferentially extending conductor embedded in a flexible, dielectric ribbon, with the view of FIG. 3 adjacent the tab of the flex seal assembly (i.e., on the left side of FIG. 1).

FIG. 4 is a top plan representation of the heating member on the side opposite the tab of the flex seal assembly (i.e., on the right side of FIG. 1).

FIG. 5 is a top plan representation of the flex seal assembly view of FIG. 3 illustrating a plurality of concentric rings of sealing material aligned with the embedded conductor in FIG. 3, the sealing material preferably comprising solder.

FIG. 6 is a top plan representation of the flex seal assembly view of FIG. 4 illustrating the plurality of concentric rings of sealing material which are substantially aligned with the embedded conductor in FIG. 4.

FIG. 7 is an alternative representation of the plurality of concentric rings of sealing material which are substantially aligned with the embedded conductor of FIG. 4 and which are generally arranged as a continuous spiral.

FIG. 8 is a side elevational, cross-sectional representation of the heating member of FIGS. 3 and 4.

FIG. 9 is a side elevational, cross-sectional representation of the flex seal assembly in accordance with a preferred embodiment.

FIG. 10 is a side elevational, cross-sectional representation of the flex seal assembly in accordance with an alternative preferred embodiment.

FIG. 11 is a side elevational, cross-sectional representation of a portion of the flex seal assembly upon installation between the top cover and base deck of the device housing.

FIG. 12 provides a graphical representation of various temperature curves for the sealing material at different power dissipation levels.

FIGS. 13 and 14 provide yet another alternative embodiment in which the sealing material is provisioned on the respective housing surfaces instead of on the flex seal assembly.

FIG. 15 is a flow chart for a HOUSING SEAL FORMATION routine, generally illustrative of steps carried out in accordance with preferred embodiments of the present invention to form a hermetic seal using the flex seal assembly.

FIG. 16 is a flow chart for a HOUSING SEAL RELEASE routine, generally illustrative of steps carried out in accordance with preferred embodiments of the present invention to open and subsequently reseal a housing sealed in accordance with the routine of FIG. 15.

Detailed Description

FIG. 1 provides a top plan representation of a data storage device 100 constructed in accordance with preferred embodiments of the present invention. The data storage device is preferably characterized as a disc drive of the type which magnetically stores and retrieves digital data from and to a host computer device.

The device includes an enclosed housing 101 which defines an internal environment for the drive. The housing 101 is formed by a pair of substantially planar housing members including a base deck 102 and a top cover 104 (shown in partial cut-away in FIG. 1).

The base deck 102 supports a spindle motor 106 which rotates a plurality of data storage discs 108 at a constant high speed. A rotary actuator 110 supports a number of data transducing heads 112 adjacent the disc surfaces. The heads 112 are hydrodynamically supported adjacent the disc surfaces via recirculating fluidic currents established by the high speed rotation of the discs 108.

The actuator 110 is pivotally rotated by an actuator motor 114, preferably characterized as a voice coil motor, VCM. As the actuator 110 rotates, the heads 112 are brought into alignment with data tracks (not shown) defined on the disc surfaces. A plenum assembly 116 channels fluidic currents through a pass-through recirculation filter (not shown) and further accommodates a relatively large block of adsorbent filtering material (also not shown).

Interposed between the housing members 102, 104 is a flex seal assembly 120 which is configured to establish a seal against the exterior environment outside the device 100. Preferably, the seal is characterized as a hermetic seal so that, upon sealing, the housing 101 is supplied with an inert gas atmosphere (e.g., helium) at a selected atmospheric pressure. The seal assembly 120 retains the internally contained fluid and further prevents the ingress of fluid-borne contaminants from the external environment for the operational life of the device 100.

FIG. 2 provides a cross-sectional representation of the assembled housing 101 to generally illustrate a preferred placement of the flex seal assembly 120 between the base deck 102 and top cover 104. A plurality of fasteners 122 are

used to compress the flex seal assembly 120 between the respective housing members. The fasteners 122 are routed through apertures in the top cover 104, pass adjacent the exterior of the flex seal assembly 120, and engage threaded apertures 124 in the base deck (FIG. 1).

With reference to FIGS. 3 and 4, the flex seal assembly 120 is formed of a heating member 126 comprising a circumferentially extending conductor 128 embedded in a thin-film, flexible, dielectric ribbon 130. The ribbon 130 is flat (i.e., has a substantially greater width than thickness) and has a closed, substantially o-shaped configuration that allows the flex seal assembly 120 to circumferentially extend adjacent the periphery of the housing 101. A particularly suitable material for the ribbon 130 is KAPTON® polyimide film commercially available from E. I. du Pont de Nemours and Company Corporation, Circleville, Ohio, USA.

A tab 132 projects from the member 126 so as to be accessible from the exterior of the housing 101 upon installation of the flex seal assembly 120 between the housing members 102, 104. The tab 132 supports a pair of electrically conductive pads 134 placed in electrical communication with opposing ends 136 of the embedded conductor 128. The pads 134 facilitate interconnection with electrical contacts from a suitable power source (not shown) to pass current along the length of the conductor 128.

FIG. 3 illustrates relevant portions of the top side of the heating member 126 proximate the tab 132 (i.e., generally corresponding to the left side of FIG. 1), while FIG. 4 illustrates relevant portions of the top side of the heating member 126 at a distal location opposite the tab 132 (i.e., generally corresponding to the right side of FIG. 1). It will be noted from these figures that the conductor 130 comprises an elongated, embedded electrical trace that makes a plurality of adjacent u-shaped turns 138 ("double-backs") as the conductor 130 weaves around each half of the ribbon 130 in turn. Other circumferentially extending routings of the conductor 130 can readily be employed, including configurations in which the turns 138 are placed at different locations around the peripheral extent of the flex seal assembly 120.

As shown in FIGS. 5 and 6, a number of concentric rings of sealing material 140 are disposed on the heating member 126 adjacent the various passes

made by the conductor 130. The sealing material 140 preferably comprises solder, but can alternatively comprise other heat activated, low permeable fusing materials such as certain types of thermoset adhesives. The rings of sealing material 140 are preferably provided both on the top and on the bottom sides of the flex seal assembly 120 (only the top sides are shown in FIGS. 5 and 6). A total of eight (8) rings of the sealing material 140 are shown, although other numbers of rings can readily be used as desired, including a single ring or a number greater than eight (8).

Preferably, each of the concentric rings 140 is a closed, discrete ring which is separated from the remaining rings by an intervening circumferentially extending gap. That is, the innermost ring is nested within and surrounded (in a noncontacting relationship) by the next innermost ring, and so on.

In an alternative embodiment, the concentric rings of sealing material 140 are formed as a continuous spiral which makes multiple adjacent loops around the periphery of the seal assembly 120, such as represented in FIG. 7 (not to scale). In this embodiment the ends of the spiral are open to create a diffusion tube path 146 that extends in the gaps between adjacent spiral loops to provide fluidic communication between the interior and exterior environments. Alternatively, the ends of the spiral (as well as selected intermediate portions, as desired) can be closed so as to form a complete, hermetic seal as before.

FIG. 8 shows a cross-sectional view of the heating member 126 of FIGS. 3 and 4 to illustrate a preferred manner in which the conductor 128 is embedded in the flex ribbon 130. The view in FIG. 8 is generally taken along a length of the conductor 128.

FIG. 9 provides a cross-sectional view of the completed seal assembly 120. The view in FIG. 9 is generally normal to the view of FIG. 8 and cuts across all eight passes of the conductor 128 and all eight rings of the sealing material 140. In the embodiment of FIG. 9, the sealing material 140 extends through the dielectric material of the ribbon 130 and directly contacts the conductor 128. An alternative embodiment in which the dielectric material is interposed between the sealing material 140 and the conductor 128 is shown in FIG. 10.

As mentioned above, application of sufficient current to the conductor 128 causes the sealing material 140 to undergo a sufficient increase in temperature to

transition to a viscous, flowable state and fuse to the facing housing member. Upon cooling, a resulting series of hardened seal joints 142 are formed at the boundary interfaces, as represented in FIG. 11.

Preferably, the sealing material 140 is solder, the base deck 102 and top cover 104 are stamped or cast aluminum, and gold or similar plated features (not shown) are provided on the base deck 102 and top cover 104 to facilitate adequate wetting and attachment between the flex seal and the housing members to provide a hermetic seal through the cross-sectional width (indicated by arrow 144) in each of the sealing joints 142. The flex circuit 130 can likewise be plated with gold or a similar material (not shown) to achieve the requisite "wetting" between the flex circuit 130 and the housing members.

FIG. 12 provides a graphical representation of a temperature curve 150 plotted against an elapsed time x-axis 152 (in seconds) and a temperature y-axis 154 (in degrees Celsius). As shown by FIG. 12, it has been found in one configuration that a power (I^2R) dissipation within the conductor 128 of about 120 watts per linear inch will raise the temperature of the solder to an appropriate fusing temperature of about 220 °C in about two (2) seconds, allowing the sealing operation to be carried out in a fast and efficient manner.

FIGS. 13 and 14 illustrate another preferred embodiment in which the sealing material 140 is initially provided on the respective housing members 102, 104 instead of on the flex ribbon 130. For reference, FIG. 13 shows the housing prior to the sealing operation and FIG. 14 represents the housing after completion of the sealing operation.

Retention grooves such as shown at 155, 156 can be advantageously used to retain and locate the sealing material 140. One or more alignment pins 157 and corresponding pin apertures 158, 159 can be utilized to ensure alignment of the sealing material 140 with the conductor 128.

To summarize the foregoing discussion, FIG. 13 provides a flow chart for a HOUSING SEAL FORMATION routine 160. It is contemplated that the routine of FIG. 15 can be adapted in an automated manufacturing process wherein a population of nominally identical housing seals are concurrently and/or sequentially formed.

At step 162, opposing first and second housing members (such as 102, 104) and a flex seal assembly (such as 120) are provided. The flex seal assembly 120 is placed onto the first housing member (in this case, the base deck 102) at step 164. Appropriate keying features can be provided in the seal assembly and/or housing member (such as the pin 158) to ensure correct alignment and retention of the respective members in the desired orientation.

The second housing member (top cover 104) is next placed onto the flex seal assembly 120 at step 166. Preferably, fasteners (such as 122) are installed during this step to mechanically affix the second housing member to the first housing member and compress the flex seal assembly therebetween.

Current is applied to the flex seal assembly 120 at step 168 to fuse the sealing material 140 to the housing members. This is preferably carried out by robotically controlled contacts which locate and engage the conductive pads 134 on the tab 132 and apply the appropriate current for a specified period of time sufficient to ensure complete heating and flow of the sealing material 140. This step further contemplates the removal of the contacts and a short cooling time during which the heated sealing material hardens to form the corresponding concentric rings of seal joints 142 shown in FIG. 11.

As mentioned above, the rings of sealing material 140 are preferably configured to form a hermetic seal so as to fully isolate the interior of the housing 101 from the exterior environment during the operational life of the device 100. In this case, an additional step shown at 170 is preferably carried out during which the existing (e.g., ambient air) atmosphere is evacuated and replaced with the desired (e.g., helium) atmosphere. The process then ends at step 172.

It is contemplated that the seal formed by the routine 160 of FIG. 13 will remain intact for the operational life of the device 100. However, it is contemplated that from time to time it may be desirable to subsequently release (break) the seal and open the housing for manufacturing rework or engineering evaluation purposes. Accordingly, FIG. 16 provides a HOUSING SEAL RELEASE routine 180 illustrative of preferred steps to release the seal formed by the routine 160 of FIG. 15.

At step 182, the aforementioned fasteners 122 used to mechanically affix the top cover to the base deck are removed, and sufficient current is applied to the

pads 134 to soften the sealing material 140. This loosens the seal so that the second housing member (top cover) can be removed at step 184, permitting the desired evaluation and/or rework steps.

While the flex seal assembly 120 can be configured in certain applications to be reusable, it is contemplated that in most cases the assembly will be a one-time use component. Thus, after the evaluation and/or rework steps are completed, the originally installed flex seal assembly is discarded and a new, replacement flex seal assembly is installed at step 186.

As before, the second housing member is again affixed to the first housing member at step 188, current is applied to the second, replacement flex seal assembly to reestablish the housing seal at step 190, and as desired, the housing 101 is filled with the appropriate fluid at step 192. The process then ends at step 194.

It will be recognized that the presence of the external tab 134 readily facilitates the ability to carry out the routine of FIG. 16. Hence, it is contemplated that the tab 134 is folded down and adhered to the side of the housing 101 at the conclusion of the routine of FIG. 15 to permit subsequent access to the tab, as necessary. Alternatively, the tab 134 can be allowed to remain in place as depicted in FIG. 2 until all manufacturing steps are successfully completed and the device 100 is ready for shipment, at which point the tab 134 is cut off and discarded.

Advantages of the flex seal assembly 120 as described herein include the ability to provide a low cost, easily manufacturable seal suitable for use in hermetic designs. As desired, the use of multiple rings enhances the capability of the seal to retain a low density inert atmosphere.

The use of solder (or other low permeable sealing material) generally provides a superior seal as compared to other materials such as formed-in-place elastomeric gaskets. Photolithography and similar material deposition techniques can be used to form the various features of the flex seal assembly 120 in a precise and cost effective manner.

The flex seal assembly is contemplated as providing a hermetic seal solution that costs significantly less than existing solutions that rely on precision-formed metal c-shaped or similar gasket seals and precision machined mating surfaces. The flexible nature of the flex seal assembly generally makes the

assembly less susceptible to handling damage as compared to these other hermetic seal solutions.

While preferred embodiments contemplate that the flex seal assembly provides a complete, hermetic seal so that nominally no fluidic or contaminant migration occurs across the seal boundary for the life of the device 100, as mentioned above the concentric rings can be alternatively arranged in a continuous spiral or similar fashion (FIG. 7) to form a diffusion path 146 that passes along the space between adjacent joints, thereby providing pressure equalization between the interior and exterior environments.

Such a path could conceivably be several linear feet long; for example, a 3-1/2 inch form factor device with about a 20 inch circumference and having a diffusion path with seven passes (between eight concentric rings) would provide an overall diffusion tube length of about 140 inches, or about twelve feet. This would provide a significantly greater wall surface area to entrap contaminants within the diffusion path as compared to existing diffusion path designs. Thus, it will be noted that the flex seal assembly 120 has utility in both hermetically sealed and non-hermetically sealed applications.

It will now be understood that the present invention (as embodied herein and as claimed below) is generally directed to an apparatus and method for sealing a housing (such as a housing 101 of a data storage device 100).

In one embodiment, the housing is formed of opposing, substantially planar housing members (such as 102, 104). A peripherally extending flex seal assembly (such as 120) is interposed between the first and second housing members and comprises a flexible, thin-film heating member (such as 126) and at least one ring of sealing material (such as 140) disposed adjacent the heating member. The sealing material is preferably solder or a low permeable, thermoset adhesive.

Dissipation of heat from current applied to the heating member causes the at least one ring of sealing material to fuse to at least the first housing member to form a corresponding number of hardened seal joints (such as 142).

Preferably, the heating member comprises an elongated conductor (such as 128) embedded within a dielectric ribbon (such as 130). At least one fastener (such as 122) is preferably used to affix the first housing member to the second housing member and compress the flex seal assembly therebetween.

In some embodiments, the hardened seal joints are arranged into a plurality of nested, discrete rings each in a noncontacting relationship with the remaining rings, thereby facilitating the formation of a hermetic seal between the interior of the housing and the exterior environment. In other embodiments, the hardened seal joints are arranged as a continuously extending spiral to facilitate the creation of an elongated diffusion path (such as 146) to permit pressure equalization and contaminant entrapment between the interior and exterior environments.

Preferably, a first set of the rings of sealing material is placed on a first side of the heating member to fuse with the first housing member. A second set of the rings of sealing material is placed on an opposing, second side of the heating member to fuse with the second housing member (such as illustrated in FIGS. 9-11 and FIGS. 13-14).

In another embodiment, a flex seal assembly (such as 120) is provided as described above to establish a seal between opposing first and second housing members (such as 102, 104).

In another embodiment, a housing seal is formed by providing opposing, substantially planar first and second housing members (such as by step 162), placing a flex seal assembly as described above between the first and second housing members (such as by steps 164, 166), and then applying current to the heating member to fuse one or more rings of sealing material to at least the first housing member to form a corresponding plurality of hardened, concentric seal joints (such as by step 168).

The method further preferably comprises a step of installing at least one fastener to affix the first housing member to the second housing member to compress the flex seal assembly therebetween prior to the applying current step.

The housing is subsequently unsealed by reapplying current to the heating member to loosen the sealing material (such as by step 182), and removing the second housing member from the first housing member (such as by step 184).

For purposes of the appended claims, the recited means for sealing will be understood consistent with the foregoing discussion to correspond to the disclosed flex seal assembly 120 as represented in FIGS. 1-14. Non-flexible, rigid structures do not fall into the scope of this element and are expressly excluded from the definition of an equivalent.

The further recitation of the means for sealing as establishing a diffusion path will be understood consistent with the foregoing discussion to correspond to the arrangement of the sealing material 140 of the flex seal assembly 120 into a continuously extending spiral or similar arrangement with open, opposing ends, as represented in FIG. 7.

The recited steps for sealing will be understood consistent with the foregoing discussion to correspond to at least steps 164, 166 and 168 of FIG. 15.

It is to be understood that even though numerous characteristics and advantages of various embodiments of the present invention have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the invention, this detailed description is illustrative only, and changes may be made in detail, especially in matters of structure and arrangements of parts within the principles of the present invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. For example, the particular elements may vary depending on the particular application of the housing without departing from the spirit and scope of the present invention.

In addition, although the embodiments described herein are directed to the hermetic sealing of a data storage device housing, it will be appreciated by those skilled in the art that the housing can be used for various other types of sealed enclosures without departing from the spirit and scope of the claimed invention.